





GATE @ IPHC Strasbourg : *overview of ongoing work in radioprotection*

N. Arbor (nicolas.arbor@iphc.cnrs.fr)

2019 GATE Technical Meeting Lyon – 04/07/2019

DeSIs (Dosimetry Simulation Instrumentation)

- Medical / Industrial / Environmental applications of nuclear physics :
 - 1) Detection
 - CMOS sensors
 - neutron detectors
 - gamma spectrometry
 - passive dosimetry (TLD, SNTD, RPL, ...)
 - 2) Monte Carlo simulation
 - micro-dosimetry (Geant4-DNA)
 - dosimetry/radioprotection (Geant4, GATE, MCNP)
- Members : 4 researchers , 2 engineers, 1 Post-Doc, 2 PhD



GATE @ IPHC

- Monte Carlo medical dosimetry
 - Organ dose in interventional radiology
 - In/out-of field dosimetry in radiotherapy
 - Dosimetry in nuclear medicine (90Y radioembolization)

Nuclear activation

- Neutrons production in hadron therapy
- Industrial food irradiation (photo-nuclear activation)
- Radioactivity measurements
 - Airborne gamma spectrometry

GATE @ IPHC

- Monte Carlo medical dosimetry
 - Organ dose in interventional radiology
 - In/out-of field dosimetry in radiotherapy
 - Dosimetry in nuclear medicine (90Y radioembolization)
- Nuclear activation
 - Neutrons production in hadron therapy
 - Industrial food irradiation (photo-nuclear activation)
- Radioactivity measurements
 - Airborne gamma spectrometry

Organ Dose in Interventional Radiology (IR)

- Minimally invasive image-guided diagnosis and treatment of diseases
- Angiography, embolization, radiofrequency ablation, ...
- High doses delivered to the patient (some Gy to the skin, some 100 mSv to the organs)





Figure 2. Histogram of cumulative dose for 382 instances of neuroembolization. Procedures include embolization of head, brain, and neck lesions.

RAD-IR Study, Miller et al., 2003

Organ Dose in Interventional Radiology (IR)

Goal : organ dose calculation in interventional radiology using DACS system (Dose Archiving and Communication System)

Collaboration : IPHC – GE– Mulhouse Hospital



(Estelle Spasic (GE), Rui Guerra (GHR), Zoé Corfield (GHR), Nicolas Arbor (IPHC))

Project :

- GE DoseWatch™ (DW) is a multi-modality and multi-vendor DACS system
- For interventional radiology, DW already proposed skin dose map functionalities
- What about organ dose calculation ? (VirtualDoseIR, homemade algorithm, ...)

 \Rightarrow What precision can be achieved for organ dose calculation based on a DACS system ?

- multi-vendor 🗇 machine independent
- DICOM based 🗇 missing/imprecise information
- IR uncertainties 🗇 beam modelling, patient positioning, ...

Organ Dose in Interventional Radiology



GE DoseWatch : skin dose in interventional radiology

Organ Dose in Interventional Radiology

GATE applications :

...

- Reference for organ dose calculation (experimental validation ATOM CIRS + TLD) :
 - Interventional radiology installation modelling (Philips Allura Xper FD20) :

X-ray beam (spectra, anode heel effect) collimation and filtering systems patient table



- Python/GATE tools for DICOM information extraction : simulation of full exam based on DICOM data (RDSR)
 3D patient dose maps calculations
- Production of MC database (and/or correction factors) for analytical dose algorithm (example : VirtualDose-IR database = 270000 MCNP simulations on 21 phantoms)

- Secondary neutrons produced by beam nuclear interactions (accelerator, patient)
- Neutron dose is currently not computed by clinical TPS
- Neutron spectrum \Leftrightarrow precise dose calculations (large discrepancies in literature)



Goal : Neutrons characteristics (energy, angle, ...) as a function of beam parameters

Collaboration : IPHC, Centre Antoine Lacassagne



(Marie Vidal (CAL), Daniel Husson (IPHC), Stephane Higueret (IPHC), Nicolas Arbor (IPHC))

Project :

- Develop a Recoil Proton Telescope (RPT) for neutron spectrometry
- Develop small-size CMOS sensors for in-phantom thermal/fast neutron counting
- Use systems to study neutron production and dosimetry in hadron therapy

 \Rightarrow How to improve neutron dose calculations in clinical TPS ?



GATE applications :

- Detector design and prototype optimization (CMOS sensors, ...)
- Test detector performances in a realistic clinical setup (room, beam, patient, ...)
- Neutron production physics in Geant4 (also interested in photo-nuclear activation)



Airborne Gamma Spectrometry

- Helicopter is currently the reference method to monitor radioactivity on large area sites
- Drone-borne solution is cheaper, easier...but detector size is divided by 50



• Various applications require low detection limits :



Environmental monitoring



Radioactive waste storage



Geology, agriculture

Airborne Gamma Spectrometry

Goal : Environmental radioactivity measurements with drone-borne system

Collaboration : IPHC, SATT Conectus



(Emilien Wilhelm (SATT-IPHC), Julien Masseron (SATT-IPHC), Nicolas Arbor (IPHC))

Project :

- Drone-borne gamma spectrometry system
- Data analysis framework based on MC database for spectra processing

 \Rightarrow Access to radionuclide identification and absolute activity by dealing with :

- very large statistical fluctuations (altitude, 1s acquisition time)
- complex background environment (spatial variability, air radon, ...)

Airborne Gamma Spectrometry

• Data processing : analyse raw data to extract radionuclide spectra



Airborne gamma spectrometry

GATE applications :

• Use MC database to correct radionuclide spectra and compute absolute activity



Conclusion

- Various nuclear physics applications using GATE :
 - medical : patient dosimetry in imaging and therapy
 - industrial : sterilisation process (γ/e^{-} beams)
 - environmental : radioactivity monitoring

• Open (and happy) to discuss / share tools / collaborate

 New PhD student (Clement Corneille) starting in October 2019 on neutron production in hadron therapy



Back Up

In/Out-of field Dose in Radiotherapy (RT)

Goal : patient dosimetry in VMAT radiotherapy

Collaboration : IPHC–Centre Paul Strauss-CREATIS



(Philippe Meyer (CPS), Jean Michel Létang (CREATIS), Nicolas Arbor (IPHC))

Project :

- DICOM based framework for VMAT dose calculations in RT
- Photon and neutron 3D dose calculations

⇒ How to complete Treatment Planning System calculations for specific cases ?

- skin dose in breast cancer treatment

- out-of-field dose (photon, neutron)

N. Arbor, et al.,, « A GATE/Geant4 Monte Carlo toolkit for surface dose calculation in VMAT breast cancer radiotherapy », Physica Medica 61 (**2019**)

H. Elazhar et al., « Neutron variance reduction technique for GATE Monte Carlo dose calculation in radiotherapy », Physics in Medicine and Biology 2018

2019 GATE Collaboration Meeting – N. Arbor

In/Out-of field Dose in Radiotherapy (RT)

GATE applications :

Python/GATE framework for VMAT dose calculations (Varian NovalisTx)



2019 GATE Collaboration Meeting – N. Arbor